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OBSERVATIONS

ON THE

VENTILATION OF ROOMS, &c.

CHAP. I.

*A View of the Properties of the Air, upon which the
Operation of Chimneys depends.*

THE science of hydrostatics, which explains the laws and properties of watery fluids, was brought to a considerable degree of perfection by the celebrated Archimedes, more than two hundred years before the Christian era.

On this science, the philosophers of later times have founded their admirable doctrine of the pressure of the air. Galileo, from analogical reasoning, first suggested the idea, that air, though a light and invifible fluid, muſt

yet be subject to the general law of gravitation, by which water and all other bodies are governed. Torricelli afterward undertook, by a series of nice experiments, to ascertain the truth of his great master's conjecture, and at length happily succeeded in confirming it beyond a possibility of contradiction. Thus pneumatics became a branch of science at so late a period as the sixteenth century. Before that time the air, from its invisibility and apparent levity, had been considered as totally devoid of weight.

The general properties of the air are now fully understood, and have been so well elucidated by many accurate writers, that it is unnecessary for me to give any scientific explanation of them. However, as the following pages were written, not for the information of the learned, but principally with a view to instruct artificers, whose situation in life cannot afford them convenient leisure to enter on a course of philosophical reading, it seems requisite here to notice those properties of the air which have relation to the subject before us. For it is obvious, that unless a workman be thoroughly acquainted with the principles of his art, he cannot proceed to make a right application of them.

Beside the *weight* or *pressure* of the air, which is perfectly analogous to that of other fluids, it is necessary to particularize its disposition to be *rarefied* to a great degree

by the application of heat, and to be proportionally *condensed* by cold. The air is thence liable to considerable variations in its specific gravity, according to the different states of its temperature.

Since the principal phenomena respecting the ascent of smoke, either in the open air or in chimneys, are founded on these circumstances, it may not be amiss to elucidate them by a few familiar examples, in order to show how much the air is susceptible of rarefaction by heat, and of condensation by cold.

1. Let a bladder that is moderately filled with cold air, and having its neck close tied up, be brought into a warmer medium, or near the fire: the air included will then immediately expand itself, and fully distend the bladder.

2. Let the bladder be returned into the former cold medium; and the air contained in it will be condensed or reduced to its pristine bulk, the bladder becoming flaccid, as before.

In order to prove that air is rendered specifically lighter by heat, and specifically heavier by cold,

1. Let the same bladder be loaded with as much weight as will just cause it to subside in cold water to the bottom of the vessel.

2. Let a quantity of hot water be added to the cold, sufficient to render the whole warm: the air will pre-

sently be rarefied, and cause the bladder to ascend more or less above the surface of the water.

3. Add cold water to the hot; and as the air condenses, the bladder will subside again to the bottom.

The *weight* or *pressure* of the air is best exemplified by that of water, which is more immediately the object of our senses.

It is an axiom in hydrostatics, that water invariably rises to the same level or horizontal line, whether it be contained in pipes, canals, lakes, or in vessels of any form whatever, capillary tubes excepted; and likewise that it perseveres in a state of rest, if no external cause interfere. Thus,

Let fig. 1, represent an inverted syphon. If water be poured into the tube at E till it rise to A, the other leg of the syphon will be filled to D in the same horizontal line. The same will be found to take place, whatever be the form of the tube, as in fig. 2, 3, and 4.

In every case the column of water A B is in equipoise to the column C D; which must be considered as owing to an equable density of the fluid.

When fluids of unequal density are put in the situation above mentioned, a very different effect is produced. The two columns cannot then remain at rest, but one will immediately overbalance the other.

Let A B, fig. 5, represent a vessel containing water, and having immersed in it a tube C D, whose lower end is closed. Now if the end of the tube C be opened, the water will ascend by it up to the same level E, as in the jar. It is obvious, that the rising of the water in the tube is caused by the pressure of the body of water in the jar, which preponderates over the weight of the column of air previously occupying the tube. Air and smoke arise in chimneys from a cause perfectly analogous to the above. For the air being susceptible of great rarefaction by heat, and of condensation by cold, becomes thence liable to considerable inequalities of pressure; for instance,

Let fig. 6, represent a tube, or inverted siphon, containing air of uniform density. The weight of the column A C will be equal to that of B C, as in the foregoing examples of the pressure of water in like circumstances. But if a fire be set at D, it will, by rarefying the column of air B C, render that specifically lighter than the column A C, and consequently destroy the equilibrium of pressure which previously subsisted between them: the latter will then preponderate over the former, and raise it up. As the column A C descends, it must pass through the fire at D: hence BD being kept constantly rarefied, will always ascend, from the superior pressure of the other column of air; and thus they would continue to

act, if no external cause interfered, till the equilibrium should be restored by an equal degree of heat.

These examples sufficiently account for the ascent of the rarefied air and smoke in chimneys, from the superior weight of the external air. Yet however obvious the principle may appear to be, nothing is more common than to see the construction of buildings interfering with it. Thus, in fig. 6, if we suppose the aperture A to be inadvertently stopped, the column A C could not descend, nor the column B C ascend, any more than if the aperture at B was closed up: the smoke therefore accumulates, its vehicle being now stagnant; and it will be diffused through the column A C so long as the free circulation of air is interrupted at A.

I may with truth aver that, for the most part, chimneys smoke from a cause perfectly similar to this; and hence appears the necessity of uniting some knowledge of pneumatics with geometrical science, if we wish to have our dwellings pleasant and healthful as well as durable.

I think it proper in this place to observe, that whenever fires are made in the open air, the smoke ascends from them in a perpendicular direction, provided the weather be calm. This does not happen altogether because smoke is lighter than air, but is more owing to the ascent of rarefied air, which acts as a vehicle to the

smoke. We need not from hence infer, that a perpendicular direction is essentially requisite to the free ascent of smoke. The fact is, in whatever direction water will descend by its gravity, rarefied air will ascend in the same by its levity ; so that the form or construction of chimneys will admit of great variety, without inconvenience.

For example, take the forms represented in fig. 7 and 8, and suppose the fire to be placed at D. The rarefied air and smoke will ascend through the crooked tubes B C as well as they would in a straight one. Or the smoke will ascend from the fire D to B with the same facility as it would through O A, supposing the fire placed at O.

What has been already said, may seem abundantly to illustrate the effects arising from the rarefaction of air in tubes or chimneys. I think, however, considering for whom this treatise is principally intended, that it will not be amiss to add a few more examples, and rather err on the side of superfluity than otherwise.

Let us then suppose a tube as represented, fig. 9, and containing a fire at E. In this case the air would become equally rarefied from E toward C, and toward D. Therefore the columns A C and B D partaking equally of the heat, must remain at rest, as neither of them could preponderate over the other. This equilibrium

might however be destroyed by flight causes. If the wind should blow into the aperture A and not into B, it must give the heat a direction toward D, in consequence of which the column BD, becoming more rarefied than AC, would ascend, so long as the cause continued to act.

Let us next suppose a fire to be placed at G, and another at F. If the heat is not equal in the two columns AF and BG, the hottest column will ascend and draw the smoke of the other downward through its fire.

On this principle the stoves in the Bank of England are constituted. I shall therefore give some further illustration of it.

The requisite is, to make a fire at A, fig. 10, the smoke from whence shall not rise upward, but descend from A to B, and after passing under the floor, as from B to D, shall ascend from D toward E, in order to be discharged at C, and thereby to keep the room in which A is placed, totally clear from smoke.

To produce this effect, a fire must be previously made on a grate at E, with an iron door closely fitted, so as to prevent the access of air from without. The column CD will then become much rarefied. Therefore, if a moderate fire be placed in the stove A, the smoke from it will not ascend, but pass downward un-

der the flooring B D, and be all discharged through the chimney E C. In this direction the current of air and smoke will continue so long as the fire is kept up at E^{*}; and no smoke can arise in the room containing the stove A. The distance from A to E need not be precisely limited: whether we suppose it three feet, or one hundred, the process may go on sufficiently well. However, if the space between the two tubes is made very great, the force of ascent in C D will be considerably diminished.

* Were the fire at A wholly inclosed, the smoke must necessarily pass through the tubes A B, D C, without any fire at E; on which principle the stoves in Germany are constructed.

C H A P. II.

On the Ventilation of Rooms, and the Construction of Chimneys.

BEFORE we enter upon the application of the foregoing principles, it is requisite to observe, that the dimensions of chimneys must bear some proportion to the quantity of fuel which their different purposes require in parlours, chambers, or kitchens.

Let us suppose the whole consumption of coal in a parlour to be one hundred weight in twelve hours, and the area of the chimney required to be 196 square inches. If then, in another situation, two hundred weight be the consumption within the same time, the area of a chimney adapted to discharge freely the increased quantity of smoke in this case, should be nearly double, or equal to 392 square inches, and so in the same ratio for larger consumptions of fuel. I do not, however, mean to insist upon it, that these proportions must be adhered to invariably. Such precision is not necessary, because the ascent of smoke depends much on the degree of rarefaction in the chimney. Experience also informs us, that the tube or shaft of a chimney, whose sides

are fourteen inches each, or whose area is 196 square inches, sufficiently answers for fitting rooms or bed-chambers in general.

The area of a chimney in a large kitchen, where the family is very numerous, should be at least 588 square inches, whether its form be a square or parallelogram.

No injury can arise with regard to the ascent of the smoke from this large capacity of the shaft; whereas a too great contraction of it frequently produces very disagreeable effects, which are not easily removed. Besides, the larger the capacity of a chimney is made, the seldomer will it want cleansing.

In applying the principles stated in the last chapter, I shall begin with buildings of the most simple construction, and afterward proceed to those which are more complicated.

Let fig. 11, represent the plan of a cottage, having one chimney C, one door D, and two windows A B.

Suppose, first, the door and windows to be airtight, or so closely fitted, that they do not admit a quantity of external air sufficient to carry up the smoke in the chimney. The house will, in that case, be incommoded with smoke and stagnant air. If then a window or door be opened, the chimney obtains a supply of fresh air, and performs

its office in carrying off the smoke properly. This circumstance points out to us a remedy for the defect, by making some convenient aperture into the house; which however must be done with caution: for if the opening is either at the door or window, the stream of cold air flowing from thence will not only be unpleasant, particularly in winter, but very injurious to the inhabitants. What I should propose for the purpose, is an *air-duct*, three or four feet long, to be fixed in either corner of the room most remote from the fire, as at E; and communicating with the external air through the wall. The diameter of the duct must be from five to six inches. The air admitted by this means will ascend in a perpendicular direction to the ceiling; and being gradually diffused, will soon acquire the temperature of the room. While this process goes on, no person within is sensible of it, nor is the flame of a candle in the least disturbed by it. At the same time, smoke and stagnant air are effectually removed. If the air should be admitted near the fire, the chimney will act equally well, but the circulation through the room cannot be so perfect; for as the fresh air must take the nearest course to the chimney, it would leave that which is contained in other parts of the room nearly quiescent; whereby it would become less fit for respiration.

Let us next consider the consequences arising from two chimneys in one and the same room, as at C F fig. 12; other circumstances remaining as before.

1. If a fire be placed at C, that chimney will not smoke, although the door and windows be perfectly close; because a supply of air must come from the other chimney F, as was formerly mentioned, page 5.

2. If it were requisite to have a fire at F also, the smoke in that chimney could not ascend at all, on account of the current of air passing down it to supply C. Or reversely, if the fire were placed first at F, the chimney C would then smoke for the same reason.

To remove the defect in this case without injuring the inhabitants, and to enable both chimneys to act well at the same time, it becomes necessary to apply an air-duct, as in the foregoing instance, but in a different situation. Its capacity must also be enlarged, since two chimneys are to be supplied with air instead of one.

A duct whose side is seven inches may answer the purpose: its area will then be forty-nine inches, or nearly double to that of the former, whose side was estimated only at five inches. The most proper situation for it is at an equal distance from each fire, as at E, because a stream of air flowing up from thence will have the greatest possible effect in ventilating the room. An air-duct at any of the corners might indeed afford a sup-

ply to the chimneys, sufficient to prevent them from smoking, but could only change the internal air partially.

Let fig. 13, represent the plan of a cottage, consisting of two rooms, with the door D, and windows A B, close. A fire in the chimney C would not smoke, since it must have a constant supply of air from the chimney F. But if the wind should happen to blow in the direction from C to F, the smoke rising from C would be carried down again with the air in F, and fill both the rooms. One air-duct might here also prevent the chimneys from smoking; but with a view to ventilation, I should recommend two, situated as at E and e, which would always keep up a proper and healthy circulation of air through both the rooms.

Let fig. 14, represent the plan of an edifice, consisting of two rooms and a vestibule. Here the same circumstances will take place as were mentioned in the illustration of fig. 12. The fire at C must take its supply of air from the chimney F; consequently, if a fire be afterward made in the latter, the smoke from it must be drawn into both rooms. The mode of furnishing air may be different from that recommended in the last example: instead of ducts conveying the external air to each room, it will generally be more convenient to fix one sufficiently capacious in the vestibule; and then

to apply lesser interior ducts to one or both of the rooms adjoining. If there should be two doors in the vestibule to which air-ducts are thus applied, when the wind blows briskly from G to D (or contrariwise) the doors being open, it will occasion both the chimneys to smoke. Wherefore it is requisite to have but one external door, or to keep both constantly shut in tempestuous weather. But of this I shall say more hereafter.

Let fig. 15, represent the plan of an edifice containing three rooms on one floor. Now, if the external doors and the windows were perfectly close, a fire in any one of the chimneys, as A, would occasion the others at C and B to smoke, provided the interior doors were all open, and likewise those in any of the chambers above.

If a fire were at the same time placed at B, only the doors DE being open, both the fires would borrow their air from C; or both from B, supposing the second fire set at C.

If fires were made in all the lower rooms, the intermediate doors, and the chamber doors being open, the chimneys on the ground-floor would all of them act well; but if the door D were shut, A and B would smoke, and C only act well. If the door E were shut, the chimney in that would also smoke.

Such then are the disagreeable consequences arising from the exactness of the carpenter's work in all houses where no provision is made for admitting the external air.

It will appear from what has just been said, that the chimneys of the lower apartments often derive their supply of air from the chambers, the doors being open; and hence it is, that, when several flues are comprised in one and the same stack, the chambers are filled with smoke and soot from the operation of the fires below.

These circumstances point out the necessity of enabling the chimneys to act independently of each other, by means of one general reservoir in the lower parts of the house, from which every apartment may be separately supplied with air. Such a plan might be executed without much difficulty, and would be attended with numerous advantages. It would promote a constant circulation of pure air through the apartments; it would clear away from them the smoke and soot; it would contribute much to the preservation of furniture, books, paintings, &c. Lastly, it would prevent the diffusion of infectious effluvia from one room to another.

The importance of these objects does not require to be enforced by argument. I shall therefore proceed

to consider the mode of admitting the air, which will most effectually contribute toward the accomplishment of the several purposes above specified.

Let fig. 16, represent the plan of an edifice containing four rooms on a floor, with fundry offices underneath, and with an open communication at S to the lower apartments or cellars.

It will in this case be proper that one or more of the passages below should have a free communication with the external air: for by this means every part of the building may be amply supplied with air, which in the winter season will in some degree conform to the temperature of that within, soon after its admission, and which in summer will be cooler than the external air. A mean temperature may thus be constantly preserved within between the two extremes.

Those openings to the external air should be made on the south or southwest sides of the house; because the chimneys require most aid when the wind blows from these quarters*.

If the plan of the building will not allow of an aperture in the directions assigned, the west side is then more eligible for the purpose than any other.

Having provided for a general supply of air to the house, we should, in the next place, regulate the mode

* The air being then generally warmer and lighter.

of its admission into each room separately both above and below stairs, so as not to injure the architecture, or occasion any deformity; which may be done easily and without expence in the first construction of a building. I have employed in several instances the following method with advantage: I leave an open space between the upper part of the architrave surrounding the door, and the wall, on each side of the door, and likewise an open space between the casing and the lintel.

The air then descends between the architrave and the wall on the outside of the door, and ascends between the architrave and the wall on the inside of the room. The current thus admitted rises in a perpendicular direction toward the ceiling, and acquires the temperature of the room, circulating through it imperceptibly to the inhabitants. At the same time it prevents any accumulation of stagnant air, and removes the smoke of candles, which is otherwise very pernicious.

A similar mode of ventilation may be applied to all the rooms, however great their number, with the same beneficial effects. It renders the smallest apartments equally pleasant and healthful with the largest, and prevents the smoke from descending when the door shuts. In small rooms more especially, when they are furnished with an air-duct, it is proper to have the doors and windows as closely fitted as possible.

Although the salutary tendency of this plan must be obvious when fully considered, there still remains a prejudice against it in the minds of the multitude. They obstinately maintain that the same injuries are to be expected from air admitted in this manner, as from the cold streams of it which usually flow into a room through the crevices of the door or window. However, the plan I propose is not recommended from theoretical speculation: it has sufficiently stood the test of experience; and to that alone we can properly appeal. Beside its own peculiar advantages, it effectually prevents those disagreeable sensations, occasioned by lateral currents of air, which chill the body on one side, while it is heated on the other; nor can its operation at all produce the same dangerous consequences, since the air introduced by it, being gradually and insensibly diffused, distributes an uniform heat round the room.

I do not propose the method of ventilation above stated as the best in all possible cases. There is so great a diversity in buildings, that a variety of modes may be adapted to produce the same effect. The application of the principles must then be regulated by circumstances, and by the discretion of the architect.

A few general hints will however serve to facilitate the process. If the kitchen be connected with the house by a passage, or by any other means, it becomes

necessary to apply an air-duct of considerable size for the use of that room alone. The area of the tube should not be less than a hundred and forty-four inches in a moderate kitchen; for if the chimney there have not a full supply independently, it will draw air from some or all of the chimneys in the house.

Different modes may be adapted to answer this purpose :

1. A perforation of twelve inches square may be made in the kitchen wall near the bottom, to which a tube must be fitted as usual.

2. If circumstances do not allow of such an opening, air may be admitted by raising the sash five or six inches above the sill, and applying a board at about the same distance from the window to direct the stream of air toward the ceiling. This board should be one foot broad, or somewhat more, and may be suspended on hinges so as to let down in the night, if the window-shutters require to be then closed. In lofty kitchens, where there are small sashes, one of the windows is often hung upon an axis horizontally, so as to open or shut, at pleasure, by a line fixed to it. The inclination of the open windows affords a supply of air to the chimney, and defends the floor from rain; but it does not prevent the inconvenience from the wind blowing downward into the room.

In some rooms where it is not convenient to make a perforation, air may be admitted between the folding of the sash-frames *, by cutting away about the eighth of an inch from the frame, leaving the whole substance at each stile. This is only practicable when there are shutters on the outside, and not on the inside of the window. For by inside shutters the current of air upward is obstructed; whence it rushes through the crevices in various directions, and produces unpleasant effects.

When rooms are infested with smoke, and cannot be conveniently supplied with a current of air from without, another expedient for clearing them, is to increase the rarefaction of the air in the chimney, by contracting its opening above the fire-place †, as represented, fig. 17, which plan likewise answers other useful purposes; for when chimneys are too capacious at their

* On a plan somewhat analogous to the above, the wards of St. Thomas' Hospital were ventilated, under the direction of Mr. WHITEHURST.

In every second window, about an inch and a half of each pane in the bottom of the upper sash is cut away. A frame of glass, nearly two feet in width, is set across the window, resting upon the top of the upper sash, and fastened to it by hinges. The frame can be moved on the hinges, so as to make a greater or less angle with the window, and by that means admit more or less air at pleasure. The air which enters between the sashes being directed by the frame toward the ceiling, is diffused through the ward without any perceptible current.

† This part of the subject has been amply considered in a work, entitled, "A practical Treatise on Chimneys," first published in the *Encyclopedia Britannica*, and afterward separately.—Edinburgh, 1776.

lower part, much cold air flows into them at so great a distance from the fire, that the warm air is condensed again by it, which not only retards the ascent of the smoke, but also renders the room extremely cold. The contraction of the fire-place, as above proposed, is also serviceable in old buildings, where the smoke of two or more fires is thrown into one tube, and often falls back into some of the rooms. It does not however, in all cases, prove effectual without the application of air-ducts, as formerly directed.

A similar plan is now very generally adopted, with an intention to produce a more uniform temperature in rooms, by regulating the quantity of air to be transmitted to the chimney. If but a small quantity ascends in the chimney, it is obvious, that a proportionately small quantity must be admitted from without; and therefore more heat will be retained in the room.

One mode of executing this plan, is by a plate sliding in a groove over the fire, as at *a a* fig. 17. This groove should not be made horizontal, but to ascend about two inches from the front to the back of the chimney; and the plate should not extend quite across the chimney, but leave an opening of at least an inch wide.

Another mode adapted to the same purpose, is the register-stove, now in common use. It is more elegant than the former, and very convenient, if due

attention is paid in applying it. Both of these methods are, however, to a certain degree exceptionable, as they favour a stagnation of air in rooms, and its consequent contamination by the breath, candles, &c. They are hence inadmissible whenever there is a large concourse of people, as in assembly rooms. Indeed the application of considerable air-ducts becomes in such circumstances especially necessary; otherwise delicate constitutions suffer extremely.

It is proper to observe that air-ducts, wherever applied, should be made sufficiently capacious to answer the purposes required, since their apertures can be much more easily diminished than enlarged.

When this mode of ventilation is adopted, the air should be transmitted into rooms, if possible, wholly by the ducts; since nothing can be more prejudicial to the inhabitants than currents of air passing through the chinks of doors, windows, or pannels. These therefore should be guarded against with the utmost care. I cannot here omit the opportunity of noticing and recommending some ingenious devices lately invented with a view to fill up the space between the bottoms of doors and the floor. They obstruct the entrance of wind, rain, or snow, in tempestuous weather; and their application is so contrived as to clear the inner door of carpets or floor-cloths when it is opened.

By attending to the few simple principles laid down in the foregoing pages, rooms may be commodiously ventilated, and the smoking of chimneys may be in general prevented. It is surely better to provide for these useful purposes in the original construction of a house, than be obliged to remedy defects in regard to ventilation after the building is completed. Indeed the remedies then usually employed are seldom found to be successful: at least pots, or other additions to chimneys, afford but a very trifling advantage, while they certainly deform the edifices to which they are annexed, and are a disgrace to the science of the builder.

C H A P. III.

On external Impediments to the Ascent of Smoke in Chimneys.

I PROPOSE in this chapter to consider some external causes which may interfere with the regular ascent of smoke in chimneys, notwithstanding all the provisions for it hitherto stated ; and I shall likewise endeavour to point out the requisite means for counteracting the operation of these causes.

1. In tempestuous weather, the atmosphere meeting with more resistance on the surface of the earth than at some distance above it, we may thence infer that the upper and lower parts thereof move with different degrees of velocity ; whence it may be presumed that the winds do not move parallel to the surface, but have often a tendency toward the earth ; and consequently to blow downward in chimneys. This effect will be greater or less according to the inequalities of the country where the house is situated.

Thus, suppose the wind in the above circumstances should take the direction *ba* and *dc* in fig. 18, it

will necessarily be driven down the chimney A B, carrying along with it both the smoke and soot.

In order to remedy this inconvenience, the top of the chimney must be guarded by a pyramidical cap, the section of which is represented, fig. 19. The wind then falling upon an inclined surface, would change its direction from *b a* to *d c*, and no longer affect the rising columns of smoke. Such an addition to chimneys, it is presumed, would occasion no deformity, but rather be ornamental to the building.

The caps are composed either of stone or cast iron: the latter seems preferable, as being less expensive, and a better defence to the mortar underneath against the injuries of the weather. Iron caps, if cast about three tenths of an inch thick, will endure for ages: their weight and figure also render them not liable to be disturbed by the winds. It is not requisite to make their apertures equal to that of the chimney shaft; but the proportion should be nearly as the square of 10 to the square of 14. This contraction of the aperture answers two good purposes: it protects the shaft from rain, and in some degree defends the rising column of smoke from the external cold.

The caps need not be set underneath with brick or stone-work, but may rest on a little mortar: or if

they are only laid flat upon the brick-work, they will sufficiently answer the purpose.

2. If a house be situated where there is some local obstruction to the current of the wind, as near a tower or other high building, or at the foot of a cliff, it becomes necessary to apply over the aperture of the chimney, a cap or cover with an opening at each end, from whence the smoke may issue in directions parallel to the adjoining surface of the obstacle. A provision of this kind is frequently made by builders in such circumstances, and executed with judgment; so that little can be advanced on this subject beyond what is already practised.

As the wind generally blows in an oblique direction toward the earth, such cliffs or eminences as are represented, fig. 20, not only require that the cover should be parallel to the cliff, but that it should project five or six inches at each end beyond the perpendicular part of the chimney.

Fig. 21, gives the end view of a cap or covering proper for the chimney of a cottage, situated as in fig. 20.

Fig 22, represents the side which is parallel to the cliff, and which projects at C D, six inches beyond the edges of the chimney. It is to be observed, that two courses of brick are left out at both the open

ends, whereas on the two sides the brick-work is carried up to the cover. These covers are made of cast iron; they may be conveniently applied to chimneys consisting of many flues ranged in one line, as represented, fig. 23.

As a further aid to the caps above described, it will be proper to construct an air-duct into which the wind may blow, in order to counteract its tendency down the chimney. To elucidate this point, let us first suppose that the cottage, fig. 20, has two similar chimneys, one at each end. The apertures of both chimneys being of the same width, it is obvious that under similar circumstances the wind will blow down both of them with equal violence. But if one chimney be covered with the iron cap, fig. 21, 22, the current of air down it will be prevented: a fire being then put in this chimney, we should find that the wind would be driven down the open shaft with increased force, and ascend up the covered one. A similar effect may be produced, if in lieu of the open chimney, an air-duct be applied, as at BC, fig. 24, where A represents the wall of the cottage; for the current of air entering at B will prove instrumental in driving the smoke up the single covered chimney, fig. 20. The duct should be placed on the side of the house nearest to the cliff. The part CD should be a box of wood,

the rest, brick. If necessary, an iron grate may be laid over the aperture B.

3. Suppose an edifice to be erected on an extensive plain, or upon an eminence where there can be no obstructions likely to change the course of the wind from a horizontal to an oblique direction.

Yet even in such a situation, and without any internal defect, chimneys are apt to smoke in windy weather. The reason probably is, that the rapid motion of the wind past the building, diminishes the pressure of the air, on which the ascent of smoke depends. This conclusion is warranted by observations made on barometers in tempestuous weather, when the mercury always falls considerably in the tube.

Let fig. 25, represent the plan of an edifice consisting of two rooms, and situated as above. Now, if the wind should blow violently in the direction A B or B A, it will have no tendency to enter the door H, or any of the windows. Hence the general pressure is taken off, by which the columns of rarefied air should be raised in one or both chimneys. The smoke therefore descends, as if blown down the shaft. The pyramidical caps will not avail in this case; neither will opening the door or a window produce any effect. The only expedient which proves effectual, is the application of air-ducts through the wall on the sides

A and B. They should be constructed according to the directions given page 28, fig. 24, with the addition of a slide applied to the interior aperture of each, and which may be opened or shut as occasion requires. Thus, if the wind blows from A toward B, the aperture in A may be open, the other remaining shut; or reversely, if the direction of the wind should be from B to A. The air will then pass with force through the open duct, and abundantly supply the chimneys, causing the smoke to ascend with the same freedom as in calm weather. It may sometimes, more especially in large houses, be requisite to construct air-ducts, which shall act merely by the force of the wind, without labour or attention from the family.

For example.—In the mansion represented, fig. 16, the air-ducts may be constructed as follows: let there be openings of sufficient magnitude in the lower offices at the extremity of each passage, having vertical valves applied to each of them. These valves are to be hung with leather straps, to open inwardly at A B C D. If then the wind blow in the direction from A to C, A will be open, and C shut. If from B to D, the valve B will be open, and D shut; and so of every other direction. The size of the valves should be greater or less according to the magnitude of the building, as from six inches to two feet square. The

inside of them may be lined with hare-skin, to prevent any noise in their operation.

When a very large building is set on an exposed situation, interior currents of air frequently prove troublesome during stormy weather; for the wind, being freely transmitted along galleries and extensive passages which communicate with each other, passes by the doors of some apartments with a violent and irregular motion, and takes off the uniform pressure by which smoke is carried up the chimneys. The consequence is, that a large proportion of the smoke falls back into the rooms at such seasons. It is therefore necessary, in this case, to apply doors within the passages, or use other similar means for obstructing the currents of air. If this cannot conveniently be done, it only remains to make a plantation of trees at a proper distance from the building on the side most exposed.

Before I conclude this part of the subject, I think it proper to notice an impediment to the ascent of smoke in chimneys, occasioned by smoke-jacks, as they are at present constructed. The vanes usually fold over one another, and make so small an angle with the horizon, that the air is not permitted to ascend with freedom, nor in a sufficient quantity to carry up all the smoke. Now if the breadth of the vanes

should be reduced so as to leave an interval of three fourths of an inch between each; and if at the same time the angle be increased to twenty degrees; the alteration would be found not only sufficient to prevent a stagnation of the smoke, but likewise to improve the power of the jack.

C H A P. IV.

On the Construction of Garden Stoves.

THE different regions of the earth being subject to great variations in the length of days, in the degrees of heat and cold, of moisture and dryness, are not capable of producing all plants equally. Thus it appears that countries within the torrid zone yield pines, and a variety of other delicious fruits, which never mature spontaneously in cold, nor even in temperate climates. We are however enabled in this part of the world, by artificial means, to bring such fruits to tolerable perfection. For this purpose, it is necessary to erect some kind of edifice to protect the plants from the inclemency of our seasons; and by the application of culinary heat, nicely regulated, to supply them with air of a requisite temperature. Hothouses adapted for the culture of exotics may therefore be considered as artificial climates; and on this view, it must appear obvious, that, in order to render the operation of them effectual, their properties, as to temperature, moisture, dryness, &c. should coincide as nearly as possible with the qualities peculiar to the climate of the plants which

are to be cultivated. In all cases then, it must be of consequence to obtain, from a series of observations, an accurate knowledge of the various properties of the natural climates, in order to settle a standard, whereby to regulate the management of the artificial ones.

On these ideas are founded the ensuing plan for constructing garden stoves, which by proper modifications may be adapted to imitate every climate of the globe. One good example will however afford a sufficient illustration of the subject:—The climate of Jamaica seems most eligible for the purpose; since the productions of that island, more especially the anana, or pineapple, are the chief objects of culture in garden stoves. I shall therefore, in the first place, investigate the properties of its atmosphere and soil, through which those plants arrive at perfection without the assistance of art, and afterward endeavour to show the mode of producing similar effects of vegetation, by means of an artificial climate.

The central part of Jamaica is situated in the 18th degree of north latitude, and has therefore days and nights of nearly equal length throughout the year. There are also material changes in the temperature of its air every twenty-four hours; for the sun at his meridian altitude being nearly vertical, a great degree of heat must necessarily be produced in the course of

the day; and during the eleven or twelve hours of night the temperature will be proportionally lowered.

From these circumstances, added to the insular situation of Jamaica, arise the phenomena of land and sea breezes, which indeed are common to all the tropical islands, and admit of an easy explanation*; for the sun no sooner appears above the horizon, than heat begins to accumulate on the surface of the land, while that of the ocean suffers little change. Hence the air above the former becomes highly rarefied, and specifically lighter than the air of the sea; it therefore ascends by the superior weight or pressure of the latter; and the cooler air thus flowing in every direction toward the center of the island, constitutes what is denominated the seabreeze. In a similar manner, as evening approaches, the sun's heat gradually abates, till the two atmospheres become equally dense: a perfect calm then ensues, which remains till the air over the land, from the long absence of the sun, is more condensed than the air at sea. The latter consequently ascends by the superior weight or pressure of the former, and thus the landbreeze commences, which blows constantly till the sun appears again above the horizon. The sea and land breezes have more or less velocity, according to the relative degrees of density in the two atmospheres:

* See Mr. Whitehurst's Inquiry, third edition, page 148.

the grateful alternation of them every morning and evening serves to moderate the fervour of the climate, keeps the air in constant motion*, and thus renders the situation more favorable than it would otherwise be to the existence both of vegetables and animals.

It evidently appears from the above account, that the air of Jamaica must be subject to frequent and considerable changes of temperature; whence we may infer, that a perfect equality in the temperature of our artificial climate is not necessary.

I think it will be proper here to give, from a series of thermometrical observations, a more particular view of the temperature of Jamaica; as also of the quantity of rain which falls annually on the island; for on a knowledge of these circumstances, the construction and management of stoves intended to imitate the properties of that climate will principally depend.

The following table is the result of observations made with Fahrenheit's thermometer at Spanish Town during one year. The first column contains the months; the second, the highest degree of the thermometer in each month; the third, the lowest state of the thermometer; the fourth, the monthly variation of the thermometer; and the fifth, the annual variation.

* Sir Hans Sloane observed in 1688, that there were only 17 perfectly calm days throughout the whole year.

Spanish Town.					London.				
Month	H	L	M V	A V	Month	H	L	M V	A V
January	83	76	7		January	52	30	22	
February	85	66	19		February	52	41	11	
March	84	71	13		March	53	37	16	
April	86	67	19		April	69	40	29	
May	87	77	10		May	67	51	16	
June	88	84	4	26	June	73	60	13	44
July	88	80	8		July	74	61	13	
August	92	81	11		August	70	58	12	
September	89	77	12		September	68	56	12	
October	87	73	14		October	68	41	27	
November	79	71	8		November	53	37	16	
December	79	70	9		December	56	34	22	

From this table we may deduce that the greatest degree of heat in any month is from 80 to 90, and that the lowest degree is between 60 and 70 *. The variation of heat monthly appears to be on an average 11 degrees, and the annual variation 26 degrees.

* The heat throughout the day is more uniform in Jamaica than in our climate. Mr. Long observes, "There is seldom a variation of more than 6 to 9 degrees on the thermometer in one day at Spanish Town, observed from six in the morning to six in the afternoon."—Hist. of Jamaica, vol. 3. p. 619.

The other part of the table * is put down, in order to show the relative temperature of the atmosphere of London; and by comparison, to prove the necessity of applying artificial modes of culture to plants whose native clime is within the torrid zone.

The year 1775 was particularly selected as an instance of the great extremes of heat and cold, which occur in our own climate †.

It is not to be understood that the preceding remarks on the state of the air at Spanish Town will answer for every part of Jamaica, which abounds with ridges of mountains, as well as valleys or savannahs; so that there must be a considerable variety of temperatures in it, according to the difference of situation. It is however to be noted, that the pineapples are most luxuriant in the lowest and hottest parts of the island, where the foregoing observations on the temperature were made.

I shall next proceed to investigate the quantity of rain which falls annually in Jamaica. From the observations of Sir Hans Sloane and Mr. Long, we learn that the proportion of fair to rainy weather varies much in different years at Jamaica.

* The numbers in this latter part of the table are taken from the Philosophical Transactions for the year 1776.

† The extremes of heat and cold are often much greater than in the instance here quoted by Mr. Whitehurst. The annual variation in 1793 was not less than 57 deg.

The annexed table shows the number of rainy days at Spanish Town, as observed by Sir Hans Sloane in 1688; and likewise the number of wet days during eight successive years, beginning with 1752, from Mr. Long's account.

Sir Håns Sloane 1688.		Mr. Long 1752 to 1759 incl.	
Months.	Rainy Days.	Months.	Rainy Days.
January	9	January	6
February	8	February	17
March	6	March	19
April	no observation	April	41
May	9	May	58
June	8	June	55
July	6	July	55
August	12	August	58
September	16	September	65
October	10	October	76
November	12	November } December }	32
December	7		
Total 10×8 = 824		Total in 8 years 482	

The observations * of the latter gentleman were not indeed made at the same place, but nearly in the same parallel just within the south side of the mountains. Mr. Long himself remarks, that a greater quantity of rain may be supposed to fall there than on the level maritime parts, and less than in some places on the north side, or on the eastern or western; therefore an allowance should be made on that account. We may however safely conclude from the average of eight years, that there are not less than sixty rainy days in twelve months.

The quantity of rain falling in each day should be considered, as well as the number of wet days in a year. We have more wet days in England, but the rain falls in far less quantities. On this head Mr. Long observes: "The rains precipitate in Jamaica with an uncommon degree of violence. After being accustomed to them, we think the clouds only drop in England, but here they melt in instantaneous cascades." — "Taking the whole island throughout, 65 to 70 inches appear to be about the medium of rain that falls upon Jamaica in seasonable years."

We should likewise take into the account the falls of dew, which are so heavy in all tropical countries. Mr. Long says, "I have no measurement of the dews

* Long's Hist. of Jamaica, page 647.

which fall in Jamaica; but in many parts of the island they are very considerable, infomuch that in one of the mountainous districts, where there is a scarcity of springs, the cattle are sufficiently watered by the dew, which overspreads the herbage every morning. In general, in the mountains it is so heavy, that a person walking among the grafs, or through a cane-piece early in the morning, would soon be as wet as if he had gone through a river. It is always least before heavy rains, and most copious in the cooler months of the year. In Spanish Town the dews are much larger than at Kingston, owing perhaps to the vicinity of the Rio Cobre."

The above observations sufficiently point out how great a supply of watery fluid will be requisite for an artificial climate, designed to imitate that of Jamaica.

It now remains to make some inquiry concerning the soil, and the usual modes of treating pine plants in their native situation. Several species of pineapples have been enumerated; and we are told, that if the seeds of them were sown frequently, as many varieties of the fruit might be produced as there are of apples or pears in Europe.

Those principally noticed are,

The bog-walk pine, of a compressed form, with white flesh, and a deep green coat;

The same, with a yellow coat ;

The pyramidical, or sugar-loaf pine, with yellowish flesh, and a deep green coat.

The same, with a yellow coat.

The smooth-leaved, or king pine.

The queen pine, with leaves smooth, and sometimes spiked.

The smaller green and yellow pyramidical or Montserrat pines *.

Of these the sugar-loaf and Montserrat pines are accounted the best, or finest in flavour. The others differ much in their degrees of sweetness, acidity, and richness. They all thrive best in a sheltered situation ; and when planted in a brick mould, that is, in the clayey earth or marle of which bricks are made. Cow's dung is the manure usually employed for them. Some persons cultivate the plants on the tops of small ridges or banks, raised about 18 inches, and disposed in straight rows. They grow most luxuriantly when thus associated together : the suckers from them are also

* To the above, Mr. Long adds the wild pine, *tillandsia maxima*, which is very common in Jamaica. It may be made to grow on a broom or mop-stick fixed upright on the ground ; and therefore appears to derive its nourishment by absorption of moisture from the atmosphere. The wild pines are much the largest of the class, and grow among the thick woods of the interior mountains between the forks and on the branches of trees. Their leaves being capacious, and formed with a hollow base, become natural reservoirs of water, which often afford refreshment in dry seasons to travellers, and to animals inhabiting the woods.

stronger and finer than when they are kept at a distance from each other, and the roots are preserved cooler and moister.

From the preceding facts respecting the native climate of pine plants, we may deduce the requisite circumstances in the construction of garden stoves, adapted for their culture in this kingdom.

1. The stoves should be capacious, and freely admit the access of light or sunshine.

2. They should have a constant supply of fresh air, by some proper mode of ventilation.

3. The air transmitted should be kept at a temperature answerable to that of the natural climate.

4. It is necessary to apply water or vapour to the plants, adequate to the proportion of rain and dew which falls in Jamaica.

5. The plants should not have their roots confined in pots, but should be planted loose in common vegetable mould similar to their natural soil. — See the preceding page.

Under this last article I think it right to observe, since pines at their native place grow to greatest perfection in the common soil, whose heat is derived merely from the temperature of the surrounding atmosphere, and not from any subterraneous fire, that therefore the application of bark, as employed in our

stoves, with a view to generate additional heat at the roots of the plants, is not according to the analogy of nature, and may be deemed useless.

This opinion, so contrary to general practice, is not however theoretical. I know from experience, that a plant may remain in the same parcel of earth four successive years, and without the aid of bark produce each year very perfect fruit. The experiment was made at my request by Mr. John Sands, gardener to lord Scarfsdale, in his lordship's stove at Kidleston. A pot was provided to contain the plant, of about 14 inches diameter, and of the capacity of three gallons. This being filled with a clayey soil, well manured with old rotten dung, was placed near the flue, and not plunged in the bark-bed. The product of the plant was as follows:—In the first year, one fruit and four strong suckers, every one of which yielded the second year a fruit and three suckers. These in the third year produced three fruits and two suckers, nearly as strong as the first. In the fourth year there were two fruits, but not so large as the former. The year following the plant died, after having produced one fruit. This plant, while it remained, was generally observed to be more vigorous, and to yield finer fruit than any of those which were set at the same time in the bark-bed.

I shall in the next place add a few observations on the other requisites for an artificial climate, as above laid down.

1. The size of stoves cannot be defined by any rules respecting vegetation. Their capacity should, however, be as large as conveniency will permit. In general, stoves are constructed on too small a scale to answer the ends of them fully, and their roofs are made too low. The defect becomes greater, if there is no provision for a free circulation of air, whose temperature is properly regulated.

2. The temperature in stoves should be nearly conformable to that of the natural climate. We have seen, that the greatest degree of heat in any month at Jamaica is from 80 to 90; and that the lowest degree is between 60 and 70; that the variation of heat monthly appears to be on an average ten or twelve degrees; and that the greatest annual variation is 26 deg. We have also seen how much less in general is the heat of an English summer, and how much greater the cold of our winters. It is proper, however, to remark, that these plants, while growing in their native climate, require no protection from the weather; whence it seems unnecessary, and would be perhaps injurious to defend them from every degree of inclemency in our atmosphere.

The great end and use of stoves is in the winter season, when the plants require to be effectually sheltered from the cold winds and damps; and when the application of artificial heat also becomes necessary to counteract the severity of the weather.

Mr. Whitehurst, in his remarks on the construction of stoves, objects to a roof consisting wholly of glass, because that substance being a very quick conductor of heat, does not afford a sufficient defence against sudden alterations of heat and cold, particularly where the roof is very low. He observes further, that the moisture ascending in stoves so constructed, is soon condensed by the external cold, and drops upon the plants, doing them considerable injury, and even destroying the parts it falls upon *. In summer also, the roof being nearly at right angles with the sun about the time of the solstice, he thinks a degree of heat is often produced, which parches the plants, unless the attendants take proper care to throw a shade over them.

With a view to remedy these inconveniences, he proposes an alteration in the form of stoves. His plan will be understood from the section, fig. 26, in which only part of the roof A B is parallel to the axis of the earth, and composed of glass in the usual manner.

* This effect takes place more especially, if the stove be not properly ventilated.

The remaining part B C, inclined toward the north, is made of thatch, as being the material least liable to be affected by changes of heat and cold. The width of the building from A to D is intended to be ten feet, the height somewhat more; and the walk at the back of the bed, two feet. E D represents the surface of the soil-bed. The line *e q* marks the direction of the sun's rays at the equinox, and *w r* their direction at the winter solstice: *s s* and *s s* are the solstitial rays in summer.

As Mr. Whitehurst has proposed no material improvements on the present mode of applying heat in stoves, I shall pass over his observations on that subject. I think it, however, not amiss to mention some objections to his general plan, which have been made by experienced gardeners*.

First, It is said, that the plants set in stoves require perpendicular light, of which, according to the proposed plan, they must be in a great measure deprived, unless the stoves were made of an inconvenient and disproportionate height.

Secondly, The back part of the stove being the lowest, would not admit of tall plants being set there. If these were placed in front, they must necessarily shade what is behind them.

* Messrs. Forsyth, Driver, and Watson.

Thirdly, Though extensive stoves may be desirable, yet their capacity should consist not in height, but in width, for the sake of conveniency; the object being to raise a great number of plants with the least possible expence of fuel.

A trial has been repeatedly made of stoves with a perpendicular glass front, and a sheltered roof sloping from thence to the back shed. As these have been found by no means to answer the purpose, it is concluded that every approximation toward the upright front will be detrimental to the growth of the plants.

3. With regard to the ventilation of stoves, Mr. Whitehurst observes: The pine plants, growing in their natural climate, have the advantage of a continual change and succession of pure air, which is found essentially requisite for preserving the health both of vegetables and animals; for stagnant air soon becomes unfit for the former as well as for the latter, being contaminated by means of the perspirable matter, and other exhalations diffused through it. In natural climates, those exhalations are carried off by the motion of the winds, and replaced by fresh wholesome air, from whence both animals and vegetables derive what is essentially necessary to their existence.

The above circumstances, which are not the result of speculation, but of actual experiment, point out to

us the great outline to be followed in the construction and management of garden stoves.

A given quantity of air being presently tainted by the progress of vegetation, therefore the more capacious stoves are made the greater probability there is of their remaining healthful; yet, as capacity can never be sufficient to supply the want of a free circulation of air, it becomes proper to make some provision for this purpose, more especially when the inclemency of the weather will not permit the doors and windows to be opened *.

This provision in the artificial climate may perhaps be found as useful as the regulation of its temperature, or the admission of light, for promoting the growth of vegetables, and is therefore a subject deserving of much attention.

Beside furnishing the stove with a perpetual succession of air, warmed, but not vitiated by the fire, it is further requisite to provide for the regular discharge of that which has been vitiated by the plants.

* The caps of the glass are supposed to admit a quantity of air sufficient to prevent any stagnation of putrid effluvia. Mr. Whitehurst, however, thought that cold streams of air thus admitted must be injurious to the plants, at least in very small stoves; he therefore recommended that the windows should be constructed as nearly air-tight as possible, and that a distinct mode of ventilation should be applied, by which the air might be made warm before its entrance into the stove.

In order to make the supply of fresh air, let there be a communication from without to the void space between the flue and the pit, and let the covering of that space be perforated in many places from one end to the other. Holes of half an inch diameter will be sufficient, whether made in a straight line or otherwise, and about half a yard asunder. The holes should be made in the front part, and not in the return, as in fig. 27. The communication from the external air into the void space to be at A A. Now the greatest heat being near the fire, the air will thus be prepared for admission, before it arrives at the apertures in front. A register plate may be applied at A A, in order to regulate the quantity of air to be admitted.

With regard to the other requisite, the mode of discharging the vitiated air, and of thus producing a free circulation through the stove, Mr. Whitehurst has left no specific directions. This object may however be accomplished without much difficulty, by apertures corresponding to those above described, made in the opposite side of the building. Two or three of a moderate size, would be sufficient: their orifices in the back shed should be covered with valves, according to the plans laid down in chap. 3. page 30. The external cold air may by this means be prevented from

rushing into the stove ; and the valves will readily yield to the pressure of the expanded air within, which enters by the assigned direction.

4. Beside supplying the plants with a proportion of fresh water adequate to the quantity of rain observed in their natural situation (see table, p. 39.) Mr. Whitehurst had an idea of imitating, in his artificial climate, the fall of dews, which is so considerable in all tropical countries.

This could only be done by a cautious admission of pure watery vapour, which might afterward condense upon the plants and on the soil. A reservoir of water might be placed with this view, either within the stove, or adjoining to it. An iron or copper vessel should be fixed in contact with the flue near the fire, and have a communication with the reservoir, so as to supply itself without much trouble. The top of the vessels should open by a pipe into the stove.

In order to render this plan safe, the steam must be admitted very gradually ; the water should be kept at a heat considerably below the boiling point, and should be thoroughly reduced to vapour, on its transmission into the stove. The vapour should be directed by means of the pipe upward to the roof, so that it may condense before its descent upon the plants.

Mr. Forsyth, his majesty's gardener at Kensington, informs me that a plan of this kind was carried into execution, under his direction, in the garden of the Apothecaries Company at Chelsea, and likewise in the Duke of Northumberland's at Sion House, with the most beneficial effects. The same gentleman is of opinion, that stoves might be commodiously heated by tubes conveying steam, on a plan which would very much diminish the expence of fuel; and in which also a provision might be made for supplying the artificial dew at pleasure.

Beside the plans and illustrations above given, there are in Mr. Whitchurst's papers several other designs relating to the subject of garden stoves, but left without an explanation. They represent different forms of stoves; different situations of the fire-places, chimneys, and air-ducts; and various modes of distributing the flues in a stove. It seems however unnecessary to exhibit any of these plans engraved, as the precise intent for which they were formed, cannot now be properly ascertained.

F I N I S.

Fig. 1



